OPERATING INSTRUCTIONS FOR AMECO STANDING WAVE BRIDGE, MODEL SWB AND BRIDGE INDICATOR UNIT, MODEL BIU

INTRODUCTION TO STANDING WAVE RATIO MEASUREMENTS

It is desireable to feed the entire transmitter's output power into the transmitting antenna so that the maximum amount of RF energy can be radiated. One way to accomplish this would be to place the transmitter right at the antenna. However, this is impractical. The transmitter must be located indoors and the antenna must be located outdoors -- at the highest possible point. A transmission line must therefore be used to carry the transmitter's output to the antenna.

In order to effect the maximum transfer of power between the transmitter and the antenna, the characteristic impedance of the transmission line must be equal to the output impedance of the transmitter and must also be equal to the resistance of the antenna at the point that the transmission line is feeding the antenna. If this is so, the antenna which acts as the load on the transmission line, absorbs all the power of the line and radiates it into space. Also, the current (or voltage) at any point of the transmission line, is equal to the current (or voltage) at any other point of the transmission line.

If the antenna resistance is not equal to the line impedance or if the antenna presents a reactive load to the line, the following will occur: the transmitter's energy or power will travel along the transmission line until it hits the antenna. At that point, a portion of it will be absorbed by the antenna and radiated usefully, while a portion of it will be reflected back along the transmission line. The greater the difference between the resistance of the antenna and the impedance of the line, the greater will be the amount of power reflected back. Also, the more the reactance of the antenna, the greater will be the power reflected back to the transmitter. Depending upon its phase, the reflected current will either cancel or add to the current going to the antenna. Current (or voltage) minimums and maximums will be set up along the transmission line which we call standing waves. The Standing Wave Ratio (SWR) is a term that is used to describe the amount of standing waves on a line. It is equal to the maximum voltage (or current) divided by the minimum voltage (or current).

$$SWR = \frac{E_{max.}}{E_{min.}}$$

If the line impedance matches the load resistance, the voltage (or current) is the same along the entire transmission line and the standing wave ratio (SWR) is 1. This is the ideal situation that we try to achieve in setting up an antenna system. The standing wave ratio is actually a measure of the mismatch of impedance between the line and its load.

If the antenna load on the transmission line is PURELY RESISTIVE, the following formula can be used to determine the SWR:

$$SWR = \frac{Z_{line}}{Z_{load}} \text{ or } \frac{Z_{load}}{Z_{line}}$$

where Z_{line} is the characteristic impedance of the line and Z_{load} is the impedance of the load (antenna in this case). For example, let us assume that the characteristic impedance of the line is 50 ohms and the antenna presents a purely resistive load of 100 ohms to this line. What is the SWR?

$$SWR = \frac{100}{50} = \frac{2}{1} \text{ or 2 to 1}$$

We have placed the larger of the two impedances in the numerator so that the SWR will be expressed as a number larger than 1 or as a certain number "to" 1. Let us assume that the antenna's impedance is a pure resistance of 75 ohms in the above example. The SWR would be:

$$SWR = \frac{75}{15} = \frac{15}{10} = \frac{1.5}{1} \text{ or 1.5 to 1}$$

As stated before, the ideal situation is where the antenna's impedance is the same as the line's impedance. The SWR would then be 1 to 1. Here the antenna absorbs and radiates all the energy and none is reflected back to the transmitter.

The instrument that is used to measure SWR is called an SWR Bridge.

GENERAL USES OF THE AMECO SWR BRIDGE

A Standing Wave Ratio Bridge with its indicator is a very useful accessory for any transmitter. Its principal application is to obtain a satisfactory power match between the transmitter and the antenna. In normal operation, it is also useful as an output indicator to aid in tuning the transmitter. The SWR bridge and indicator can also be used to continuously monitor the transmitter's output. Because the SWR Bridge is left in the line at all times, the SWR can easily be measured and the condition of the antenna and transmission line are readily determined.

Other uses of the Bridge include the following: measuring the SWR in a line between the transmitter and an antenna tuner; measuring the SWR between a driver and a high power final amplifier; adjusting antenna coupling elements such as a gamma match and checking antenna resonance.

SWB/BIU DESCRIPTION

The Ameco SWB is a Standing Wave Ratio Bridge that can be used on frequencies from 1.8 Mc. to 225 Mc. Useful indications can also be had up to 450 Mc., but the SWR at these frequencies will not be as

accurate as at the lower frequencies. The design of the Ameco Bridge is based on the U.S. Naval Radio Report No. 3538 entitled "A Reflectometer for HF Band".

When the Ameco Standing Wave Ratio Bridge is used in conjuntion with the Ameco Bridge Indicator Unit, measurements of Standing Wave Ratio (VSWR), relative power and relative voltage in a coaxial line can be made. The Ameco Bridge Indicator Unit is the only indicator on the market that can be used with two, not just one, bridge units. This permits the permanent installation of two bridge units. The switching of the indicator from one bridge to another is done on the panel of the Bridge Indicator Unit. Because its insertion loss is negligible, the bridges can be left in the line all the time.

SPECIFICATIONS

Model SWB Standing Wave Bridge:

- Frequency Range - 1.8 to 225 Mc.
- Impedance - 50 ohms.
- Maximum Power Handling Capacity - 1000 watts R.F.
- Power Loss - Negligible.
- RF Connectors - Amphenol 83-1R (SO-239) UHF.

Model BIU Bridge Indicator Unit:

- Meter - 100 microamperes full scale, D'Arsonval Movement.
- Scales - SWR 1:1 to 20:1
  - % Voltage 0 to 100%
  - % Power 0 to 100%
- Potentiometer to adjust meter sensitivity.
- Switch to connect meter for forward and reflected power readings.
- A second switch to connect a second bridge unit in another part of the transmitter circuit or to a second transmitter.

WHERE TO CONNECT THE STANDING WAVE RATIO BRIDGE

1. If the transmitter feeds the antenna directly, connect the SWB between the transmitter and the antenna -- at the transmitter.
2. If the transmitter feeds an antenna tuner (match box, etc.) and the antenna tuner feeds the antenna, connect the SWB between the transmitter and the antenna tuner.
3. If the transmitter feeds a low pass filter or balun, which in turn feeds the antenna, connect the SWB between the transmitter and the filter or balun.
4. In setting up an installation where coaxial cable and a filter or antenna tuner is used, it would be advisable to check the SWR at both sides of the filter or antenna tuner. After this is done and everything is satisfactory, the bridge should be left at the transmitter side of the filter. If a really deluxe installation is desired, two bridges can be installed (one on each side of the filter or tuner) and left in the line at all times. The indicator unit has a switch to permit the use of two bridges.

Open wire transmission lines are very often tuned. This means that the SWR is normally very high. Due to the high impedance and low loss characteristics of this system, a high SWR condition is satisfactory in this case. The opposite is true of coaxial lines, which should be operated with a low SWR. It cannot be over-emphasized however, that when an antenna is fed by coaxial cable, all matching adjustments must be made at the antenna. It is impossible to match a coaxial line to an antenna by making adjustments at the transmitter or pruning the cable to an exact length.

INSTALLATION

Installation of the SWB/BIU combination to a transmitter is made in the following manner: Connect the input of the bridge to the output of the transmitter, using either a double male connector such as the Dow-Key DKF-2 or a short length of RG8/U or RG58/U coaxial cable with a PL-259 plug at each end. Connect the output end of the bridge to the transmission line leading to the antenna. Take the two wire shielded cable coming from the SWB and connect it to Terminal Strip A on the rear of the indicator unit -- connect the bare wire to the G terminal (common ground), the blue or red wire to the F terminal (forward) and connect the brown or black wire to the R terminal (reflected).

If two bridges are used with one indicator, connect one bridge to the A terminal strip as indicated above, and connect the second bridge to the B terminal strip in a similar manner.

Refer to the schematic of the BIU (Figure 2) for construction and connection information if you desire to use another make of indicator unit or a homebrew indicator unit with the Ameco SWB. In the VHF range, a 1.0 ma. meter is usually sufficient; at lower frequencies, a 100 microampere sensitivity is required.

OPERATION OF SWB/BIU

Turn the BIU knob fully counterclockwise. Set the left hand slide switch to Bridge A and the right hand slide switch to "FWD" (forward). (If you are reading Bridge B, set the left hand slide switch to Bridge B instead of Bridge A). Turn on the transmitter and allow it to warm up. Tune it as usual. With the trans-

mitter key down, adjust the BIU knob until the meter reads exactly full scale. (See Section below on "USING THE BRIDGE WITH LOW POWER TRANSMITTER" if you cannot get full scale deflection with your transmitter). Adjust the slide switch to "REFL" and read the SWR on the top scale. The reading on the top scale is the Standing Wave Ratio. For instance, if the meter reads 3, then you have an SWR of 3 to 1. If it reads 1.5 (half way between the 1 and the 2) your SWR is 1.5 to 1. If the meter reads 1 (does not move) then you have the ideal SWR of 1 to 1, etc. The corresponding reflected voltage and power readings can be obtained at the same time if they are of interest. If all the readings are satisfactory, switch back to "FWD" and operate the transmitter normally. During any transmission, the transmitter performance can be checked by glancing at the BIU meter. If the output drops for any reason, the BIU meter will show it and the percentage drop in power can also be read as an aid to locating the trouble.

USING THE BRIDGE WITH LOW POWER TRANSMITTERS

If you have a low power transmitter, particularly on the 40 or 80 meter bands, the maximum forward readings may be less than full scale. To read SWR, full scale deflection is not actually necessary. All we need is enough of a forward reading and reflected reading to get a good comparison between the two. For instance, let us assume that the maximum reading you can get in the forward position is 84 on the % voltage scale. You would then switch to "REFL". Let us assume that this reading is 21 on the % voltage scale. We divide the reflected voltage by the forward voltage to get the percentage of reflecte voltage:

$$\frac{21}{84} = \frac{1}{4} = .25 \text{ or } 25\%$$

We then look for the % voltage, in this case 25%, on the % voltage scale and read directly up to the top scale. It reads approximately 1.7. The SWR is therefore 1.7 to 1. Let us take another example. If the maximum forward % voltage is 60 and the reflected % voltage is 10, what is the SWR?

$$\frac{10}{60} = .166 \text{ or } 16.6\%$$

16.6% voltage is equivalent to approximately 1.4 on the SWR scale. The SWR is therefore approximately 1.4 to 1.

USE OF SWB/BIU AS AN OUTPUT INDICATOR

To use the bridge as an output indicator, switch to "FWD" and adjust the knob so that the meter reads about half scale. Then tune the transmitter for maximum meter indication while holding the plate current of the final stage to within its tube's ratings. You will notice when tuning a tetrode amplifier having a screen dropping resistor that the maximum output tuning point will not always be exactly the same as the point at which the plate current dips to minimum. Also, you may find that as you increase the amplifier loading, the output indicator does not increase correspondingly. The indicator may have gone through a maximum and then dropped off as the input to the amplifier is increased. You will probably also find that the power output is rather sensitive to grid excitation with a tetrode amplifier and too much grid current will be just as bad as too little grid current. You should pay more attention to the output indicator reading than to the plate current reading (except, of course, as mentioned above, you should not exceed the ratings for the tubes) because the output indicator reading actually tells you what is going into your antenna.

POWER MEASUREMENTS

The Ameco SWB/BIU combination, as it is shipped from the factory, is calibrated directly in watts for only one frequency band -- the Citizens Band (26.960 to 27.255 Mc.). (If you are interested in CB power measurements, make sure that the serial number on the BIU is the same as the serial number on the SWB when purchasing these units. These have been measured and calibrated as a pair at the factory). This calibration will be accurate only when the load is 50 ohms resistive. In other words, there must be a 1 to 1 standing wave ratio. Data for calibration of unmatched units is given below.

Because the SWR must be exactly 1 to 1 and because the sensitivity of the SWB varies with frequency, the SWB/BIU combination must be calibrated to measure power at each frequency that the user wants to measure power. This is also true of all competitive makes of bridges that have very low insertion loss and good VHF performance. The sensitivity for a given frequency and a given BIU potentiometer setting will be quite stable over a period of time. Because of this, the SWB/BIU combination can be used to check transmitter performance from time to time.

READING OUTPUT POWER

Reading output power on the Citizens Band with an Ameco SWB/BIU combination is quite simple. It is done in the following manner: Make sure that the pointer of the BIU knob points down to the letter "O" in the word "TO" when the knob is turned completely counterclockwise. Then turn the knob so that the knob's pointer points to the black dot on the panel. Move the switch to "FWD" position and read the output power on the % POWER scale - divide the scale by 10. Full scale would then be the equivalent of 10 watts: the second major division from the zero would be one watt, the 20 division would be 2 watts, etc.

It is impossible to get 5 watts of output power as indicated by the BIU meter from a transmitter whose

maximum DC power input is 5 watts. The efficiency of the final stage is always less than 100%. It is generally 50 to 60% in a CB transceiver.

CALIBRATING SWB/BIU FOR POWER READING

In order to calibrate the SWB/BIU combination to read power at other frequencies, a known amount of power must be fed into the bridge. The bridge must feed a purely resistive load of 52 ohms. Switch to "FWD" position. Adjust the BIU knob so that the known power has a good reference on the % POWER scale. Place a dot on the panel to where the knob points. This dot is now the reference setting for reading power at this frequency (assuming, of course, a 1 to 1 SWR at this frequency). A few examples will clarify this procedure: Let us assume that we are feeding 70 watts of power at 29 Mc. through the bridge. Adjust the knob so that the meter rdads 70 on the % POWER scale. Place a dot on the panel where the knob points to. This combination is now calibrated to read directly 0 to 100 watts (at 29 Mc.) on the % POWER scale.

Let us take another example. Assume that we feed 500 watts of power at 14 Mc. through the SWB/BIU combination. We adjust the BIU knob so that the meter reads 50 on the % POWER scale. We put a dot on the panel to where the knob points. This dot is now the reference point for 14 Mc. and the combination is calibrated so that full scale deflection is 1000 watts. In other words, a 0 is to be added to the numbers on the % POWER scale.

NOTES ON SWB/BIU

If you find that the BIU reads zero in the reflected power position when the transmitter is run continuously, indicating a matched line, but that there is a momentary "flick" of the needle when the transmitter is keyed, you can be fairly certain that there is a parasitic oscillation in the transmitter. Also, if you find it impossible to get a reflected reading of zero (assuming a 1 to 1 SWR), it may be because there is enough harmonic or sub-harmonic content in the transmitter output to cause a "residual" meter reading, even with perfect matching at the operating frequency.

Many operators, both commercial and amateur, worry too much about the SWR. In many top notch transmitter-antenna systems, the instructions are to try to maintain an SWR below 2:1. 2:1 represents approximately 10% reflected power which is not a serious loss. For temporary setups, even a 3:1 SWR can be reasonable.

ADJUSTING OF SWB

The position of the resistors in the SWB is critical. If the resistors are distnnbed or bent out of place, the indicated SWR will not be correct. In the event that the resistors have to be adjusted, use the following procedure: Use a pure resistance load of 50 ohms instead of the antenna. Remove the cover of the bridge and set the transmitter up on the highest frequency available -- 220 to 240 Mc. is best. Switch the indicator to "REFL" and adjust the resistor closest to you (looking from the bottom of the unit) by bending its leads A LITTLE AT A TIME until the meter reads as low as possible. Note that the grounded end of the resistor is very close to the center conductor tube and the other end is some distance away from the center donductor. This relationship must always be the same. You merely adjust by bending slightly at a point next to the soldered joints. Be careful not to disturb the other resistor. The potentiometer should be turned fully clockwise for this adjustment. Disconnect the coaxial lines from the SWB and reconnect them in the opposite direction. (input and output are reversed). Switch to "FWD" position and adjust the other resistor the same as above. Do not do any bending with the carrier on as an accidental short can damage the diode or the meter. Put the cover on the bridge and reconnect everything as usual.

SHIPMENT OF BIU

If the BIU is to be handled or shipped, turn the knob fully counterclockwise. This shorts the meter, putting a "dynamic brake" on it to prevent overswing damage to the meter.

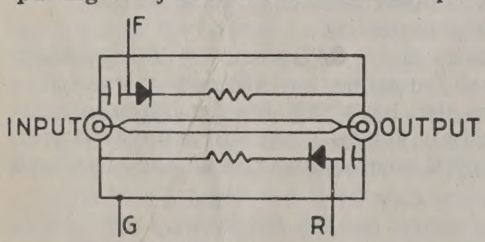

Fig. 1 - SWB Schematic

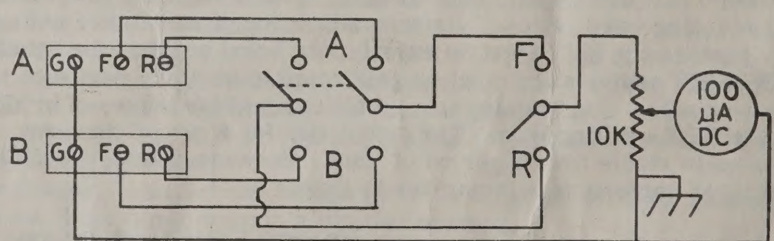

Fig. 2 - BIU Schematic

Circuit	Wire Color	Terminal
Ground	Bare (shield)	G
Forward	Blue or Red	F
Reflected	Brown or Black	R

AMECO EQUIPMENT CO. (Div. of Ameco Publishing Corp.)
275 Hillside Avenue, Williston Park, New York 11596